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THE FIRST EARTH RESOURCES TECHNOLOGY SATELLITE NEARLY TWO YEARS OF OPERATION

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Applications of Direct Interest to Developing Countries

Sao Paulo, Brazil

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ABSTRACT

The ERTS-1 spacecraft, sensor and picture processing systems have continued to perform almost flawlessly since August 1972. Registered, multi-spectral images of all major land masses of the earth, both polar and some oceanic regions are continuously made, covering daily an area of about 5 million square kilometers. The systematic repetition of these observations, which were made over most parts of the world at least once every season, and the high accuracy of thematic mapping that can be obtained from the images, have resulted in many applications that have immense potential benefits for developing countries. Among these applications are the detection and accurate mensuration of surface water; the identification and mensuration of forests, rangeland, crops and soils; the monitoring and mapping of water quality, wildlife habitats and of the effects of land use practices on food and water resources; the assessment of flooding and earthquake hazards; and the facilitation of mineral exploration.

During the past year, some hundred examples of these applications were demonstrated in North America and many other successful applications to resources surveys and management were made in each of the Asian, African, Australian, European and South American Continents. A survey of these specific applications will be given by the various invited presentations in the Seminar.

Introduction

The following is a brief status report on the performance of the ERTS-1 and an overview of some of the applications derived from the ERTS-1 images. The satellite has acquired images continuously and world wide since July 1972. Nearly one year and 11 months after launch, ERTS-1 is still alive and well. There has been much misunderstanding about the performance of the tape recorder which is still operating and capable of acquiring images practically anywhere in the world, but one of the two redundant tape recorders had to be shut off shortly after launch, because of an electrical short circuit. About seven months later, the picture storage capacity of the remaining recorder had to be considerably reduced. Nevertheless, until very recently, about 50 pictures were recorded daily all over the globe. Since the three television cameras on ERTS-1 were deactivated shortly after launch, practically all of the images, used in the many applications, stem from the "Multi Spectral Scanner (MSS)." In case of failure of this scanner, we expect to turn the cameras on again. The number of images that were produced, the total area of the world that is being covered, and the frequency with which such coverage is obtained have all exceeded our most optimistic expectations. Approximately 150 "scenes," each covering 185 x 185 km are processed daily by the NASA Data Processing Facility; in general, it takes less than three weeks until the signals that are transmitted from the satellite to the three U. S. ground stations are converted to photographic images. These images are made available to users anywhere in the world, through the appropriate data centers, within about one month.

Areal Coverage

Every 18 days, the entire globe except for the polar caps, appears within view of the ERTS sensors; but images are made only over certain preselected areas. The area covered by images transmitted directly to the three U. S. stations located in Maryland, California and Alaska amounts to almost 40 million square kilometers every 18 days which amounts to about the total land mass of North America. When the tape recorder was still operating normally, prior to April 1973, an additional 60 million square kilometers of the world outside of North America were imaged, on the average, during each 18 day cycle. The combined coverage from direct transmissions acquired by the three U. S. stations, from images stored on the on-board tape recorder and from direct transmissions to the station in western Canada, amounts to an area equivalent to more than three quarters of all the land masses of the world, every 18 days. Since April 1973, coverage by the on-board tape recorder had to be cut in half. However, fortunately just about at that time, the station in Brazil began to acquire images and is making up for the reduced coverage by the tape recorder. By the end of May 1974, more than 124,000 scenes had been imaged by ERTS. These scenes covered nearly 5 billion square kilometers. Considering that each scene is imaged in four spectral bands, there are now nearly a half million photographs available at the data centers, ready to be distributed at nominal cost, to anyone in the world who asks for them. The U. S. EROS Data Center in Sioux Falls, South Dakota, has so far received requests for nearly 150,000 individual pictures. These requests have come from every continent of the globe.

Table 1 shows the world-wide scope of the ERTS-1 investigations and applications. Test sites where investigations are being conducted are located in more than 50 countries. The governments of nearly 40 of these countries are supporting these investigations and have reached agreements with NASA for the exchange of data and findings. Images over test sites in the remaining countries are being analyzed by investigators from U.N. organizations such as the F.A.O. or from American institutions. The countless applications that have been derived from ERTS pictures by individuals or organizations who did not obtain them from NASA but purchased them from the various data centers, are not listed in the table.

Frequency of Coverage

Over the United States, where the data are transmitted directly to the acquisition stations, images were taken regardless of cloud cover during almost every one of the 37 passes that occurred over each area until the end of May 1974. Outside of North America and Brazil, images must be recorded on tape on board the satellite. Tape recordings are judiciously selected on the basis of both predicted cloud cover and of particular applications that were proposed for certain areas in advance. Over such areas as the African Sahel, South Africa, southern Asia, and central Australia, many such applications had been proposed and cloud conditions were also favorable for obtaining images. These areas were imaged, therefore, about 10-15 times during the past two years. Over other areas, such as central and northern Asia, no specific interest was expressed to NASA, therefore, only occasional images of opportunity were

taken when these areas were predicted to be cloud free. Also, there were only very few opportunities for images of northern Europe, the Arctic and Antarctica because of the persistent cloud cover, and reduced tape recorder capacity. In general, these areas were covered only 1-3 times in the two year period.

Salient Features of ERTS-1 Observations and Applications

The polychromatic or multispectral nature of the images permits the identification or measurement of the quality and composition of water, the potential water content of snow, the moisture and possible composition of soils, the types and state of vegetation cover, and factors relating to stresses on the environment. For example, water is clear, where it appears dark in all four spectral bands; it is sediment laden or contains high concentrations of nutrients, where it appears bright in the short wavelengths and dark in the long wavelengths. Vigorous vegetation appears very dark in the visible spectrum but is almost as bright as snow in the infrared, while less vigorous or diseased vegetation becomes brighter in the visible and darker in the infrared. Images in the separate spectral bands can be overlaid in color composites which display the spectral contrasts in varying shades of blue, green and red and permit, readily, the identification and measurement of these botanical, hydrographic, environmental or cultural features on the earth's surface.

The second important asset of ERTS images is the orthographic view which the satellite provides of the Earth. Vast areas are being observed at or near the nadir, to minimize the screening effect of atmospheric haze and

geometric distortion. These images constitute relatively accurate, instantaneous thematic maps on a scale of 1:250,000. With some minor loss of definition, such maps can be enlarged to a scale of 1:100,000. Even in the United States there are many areas where such thematic maps do not exist; for most areas of the world, their acquisition would be economically unfeasible. Yet, an investment of about \$10 in a multispectral ERTS picture and of an additional several hundred dollars for analysis, will provide such a thematic map almost anywhere in the world, each image covering an area of 185 x 185 km. Freedom from distortion permits the mapping of arbitrarily large areas by simply joining individual ERTS pictures such as is shown in Figure 1 for the entire United States of America. Such mosaics have been made for many other countries. A thematic map covering large portions of Mali and Niger and some portions of Upper Volta and Nigeria in Africa has been analyzed by MacLeod and investigators from these countries to determine the effects of advancing desertification in these countries and to find methods to ameliorate these effects. A discussion of the results of this analysis will be presented by MacLeod in tomorrow's session.

The ability to use ERTS pictures to identify water, crops, soils and land use features and to measure accurately the location and areal extent of these features has resulted in many practical applications in the United States. These applications could be readily adopted in the developing countries of the world. For example, a soil association map of the entire state of South Dakota was prepared from ERTS pictures by Westin,

as shown in Figure 2, at minimal cost. This map is now being used in that state by both local governments and private organizations to assess the value and productivity of large tracts of land and to help in planning land use.

Figure 3 illustrates the stark contrast between surface water and land in the infrared band. In this particular scene, a series of reservoirs for hydroelectric power generation in the southeastern U. S. are shown. The U. S. Army Corps of Engineers, who has the responsibility of making periodic inventories of such reservoirs, has used such images for this purpose and has determined the precise locations of all such reservoirs in the U. S. as well as the acreages of the larger ones. Even in the U. S. A. this census of surface water would have been impossible to make without ERTS pictures.

A similar analysis was made of the spoilage of land by strip mining operations and of the effectiveness of reclamation operations which are required by law in many states of the U. S. A. In general, the information derived from ERTS pictures about such activities is much more timely, more accurate and about 10-20 times more cost effective than that obtained from conventional surveys.

Figure 4 is a mosaic of ERTS images which have been used by Pickering, of the state of Georgia, to delineate wetlands and swamps along the coast of that state. Such surveys are particularly necessary because these wetlands provide a rich natural resource for the wildlife and shellfish of

this area which is extremely susceptible to impact by man made construction and development activities. The multitude of practical applications resulting from land use, vegetation, crop, water and soil surveys with ERTS pictures is overwhelming. They range from the assessment of insect damage to timber resources caused by the mountain pine beetles in central California, to the mapping of water sheds, forest cover and land use in the Mekong River basin of Southeast Asia. The great economy of using ERTS images is particularly obvious in the latter case, where the land is often totally inaccessible to conventional surveys.

The last and perhaps most significant asset of ERTS is that it provides regularly repetitive coverage every 18 days, depending only on cloudiness. Such sequential images have been especially useful where the run-off from snow cover is important to the water supply of large areas. The decrease of snow cover can be measured precisely from one image to the next. By means of a simple model that must be developed for each area, water run-off can be computed. This method of run-off prediction is significant in developed water sheds, as well as in those countries and water sheds where reservoirs are yet to be built and the capacity of the water supply for a particular region must be determined prior to development. Analyses of susceptibility to flood damage have also been made from sequential ERTS pictures for many river valleys of the eastern U. S. A. by Rango and Salomonson. Flood boundaries and flood paths were mapped with a precision and on a scope that would not otherwise have been economically feasible. The technical and economic benefits that could

accrue from flood plain mapping with ERTS pictures are discussed in greater detail in the paper by Castruccio and Rango.

ERTS-1 images are also being used to assess the abundance of marine resources. For example, brightness variations were observed over the Atlantic Ocean off the coast of West Africa. In September 1972, bright areas were limited to the immediate vicinity of the coast. These brighter shades of the water indicate higher concentrations of nutrients caused by upwelling along the coast. In pictures taken six months later (Figure 5), the bright area covers a much larger region, extending nearly 150 km along the coast and more than 50 km offshore. The application of those sequential images to the assessment of marine resources and to the fishing of the world's oceans is obvious. Such applications have been analyzed by Szekiela for many prominent upwelling areas of the Atlantic and Indian Oceans.

Environmental factors and events occurring within time frames of months or seasons have been observed by ERTS throughout the world. Most prominent among these is the progressive desertification of the African Sahel. It is, perhaps, less well known that ERTS pictures have been used, at least indirectly, to conduct censuses of wildlife. An inventory of the water fowl population of North America was derived from a survey of the changing water levels and number of ponds in the most prominent breeding areas. Similarly, Pedgley has monitored and assessed the breeding conditions for desert locusts in the Red Sea coastal plains of Saudi Arabia,

based on vegetation classifications made with ERTS pictures. The vegetation there is an indicator of breeding conditions for the locusts and there is a potential that through repetitive coverage, the occurrence of locust plagues could be predicted. Forest fires and grass fires have been mapped in America and Africa. The significant point here is not the detection of the fires, for which ERTS observations are made much too infrequently, but the assessment and precise measurement of the damaged areas which are necessary for reclamation and control operations. Such assessments cannot be economically performed without ERTS pictures, particularly in large and remote areas. Air pollution can become a concern even in developing countries, especially when the phenomenon extends across national boundaries. ERTS pictures have detected and traced large polluted air masses extending over several hundreds of square kilometers of rural and agricultural land of the middle Atlantic United States more than 200 km from the original sources of the pollution. The many investigations dealing with ERTS observations of land forms and applications to mineral, ground water or petroleum exploration or to earthquake and landslide hazard detections were not mentioned in this presentation, because examples of these applications will be the subject of several subsequent papers. However, the results of Krinsley are noteworthy, who inferred the bearing strengths of salt crusted playas in Iran from ERTS images taken under varying conditions of innundation. This has resulted in road transportation planning which takes into account the suitability of these salt plains for road beds and will provide

considerable saving of effort and money in the eventual road construction.

Finally, the Data Collection System on ERTS-1, which is very much overshadowed by the pictures taken with the Scanner, is also performing extremely well. Information on water flow and water quality is being transmitted daily via the satellite from remote and totally inaccessible sites of North America. The USGS has installed a Volcano Surveillance Network which includes the transmission of seismic data from Alaska, Hawaii, Washington, California, Iceland, Guatemala, El Salvador and Nicaragua. Data transmitted via ERTS have given indications, several days in advance, of a volcanic eruption in Guatemala last year.

In conclusion, the more than 140,000 scenes observed by ERTS-1 all over the world in two years, and the scores of applications that have been derived from them, have demonstrated without any doubt that earth surveys from space can provide the most effective and economic means for the solution of many resource development and management problems in all countries of the world. The data base which ERTS has accumulated in the past 23 months is already overwhelming. Failure to use it would bypass one of the most powerful and cost-effective products resulting from the space program to date.

List of Tables and Figures

Table 1. Locations of Major ERTS-1 Investigation Sites.

Figure 1. ERTS Mosaic of the Continental U. S.

2. ERTS Mosaic of South Dakota - Soil Association
3. Surface Water Identification - Southeastern U. S.
4. Wetlands and Swamps - Georgia Coast.
5. Upwelling along Northwest Coast of Africa - March, 1973.

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